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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53 (c).

Express Mail Label No. *EV335606213US*

INVENTOR(S)		
Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Jochen	Sang	Kirchheim/Teck, Germany
Andreas	Knoop	Esslingen, Germany

☐ *Additional inventors are being named on the ______ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (500 characters max)

FUEL CELL SYSTEM WITH VARIABLE COANDA AMPLIFIERS FOR GAS RECIRCULATION AND SYSTEM PRESSURE REGULATION

CORRESPONDENCE ADDRESS

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☒ Customer Number: 00500

OR

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ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages*	21	☐ CD(s), Number	
☒ Drawing(s) *Number of Sheets*	3	☒ Other (specify)	Fee Transmittal (+ copy)
☒ Application Data Sheet. See 37 CFR 1.76			

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☐ Applicant claims small entity status. See 37 CFR 1.27. — Filing Fee Amount

☒ A check or money order is enclosed to cover the filing fees. — **$160**

☐ The Director is hereby authorized to charge filing fees or credit overpayments to Deposit Account Number: **19-1090**

☐ Payment by credit card. Form PTO-2038 is attached.

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

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Respectfully submitted,			
SIGNATURE	[signature]	DATE 4/29/04	**April 29, 2004**
TYPED or PRINTED NAME	**Karl R. Hermanns**	REGISTRATION NO. *(if appropriate)*	**33,507**
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USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

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FEE TRANSMITTAL for FY 2004

Patent fees are subject to annual revision.

☐ Applicant claims small entity status. See 37 CFR 1.27.

TOTAL AMOUNT OF PAYMENT	($)	160

Complete if Known	
Application Number	
Filing Date	April 29, 2004
First Named Inventor	Jochen Sang
Examiner Name	
Art Unit	
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METHOD OF PAYMENT

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Deposit Account Number	19-1090
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FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee($)	Small Entity Fee Code	Small Entity Fee($)	Fee Description	Fee Paid
1001	770	2001	385	Utility filing fee	
1002	340	2002	170	Design filing fee	
1003	530	2003	265	Plant filing fae	
1004	770	2004	385	Reissue filing fea	
1005	160	2005	80	Provisional filing fee	160
				SUBTOTAL (1)	($) 160

2. EXTRA CLAIM FEES FOR UTILITY AND REISSUE

			Extra Claims		Fee from below		Fee Paid
Total Claims		-** =		×		=	
Independant Claims		-** =		×		=	
Multipla Dapandant						=	

Large Entity Fee Code	Large Entity Fea ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
1202	18	2202	9	Claims in excess of 20
1201	86	2201	43	Independent claims in excess of 3
1203	290	2203	145	Multiple dependent claim, if not paid
1204	86	2204	43	** *Reissue independent claims over original patent*
1205	18	2205	9	** *Reissue claims in excess of 20 and over original patent*

SUBTOTAL (2) ($)

**or number praviously paid, if greater. For Reissues, sae above

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Fee Code	Small Fee ($)	Fee Description	Fae Paid
1051	130	2051	65	Surcharge - late filing fee or oath	
1052	50	2052	25	Surcharge - late provisional filing fee or cover sheet.	
1053	130	1053	130	Non-English specification	
1812	2520	1812	2520	For filing a request for *ex parte* reexamination	
1804	920*	1804	920*	Requesting publication of SIR prior to Examiner action	
1805	1840*	1805	1840*	Requesting publication of SIR after Examiner action	
1251	110	2251	55	Extension for reply within first month	
1252	420	2252	210	Extension for reply within second month	
1253	950	2253	475	Extension for reply within third month	
1254	1480	2254	740	Extension for reply within fourth month	
1255	2010	2255	1005	Extension for reply within fifth month	
1401	330	2401	165	Notice of Appeal	
1402	330	2402	165	Filing a brief in support of an appeal	
1403	290	2403	145	Request for oral hearing	
1451	1510	1451	1510	Petition to institute a public use proceeding	
1452	110	2452	55	Petition to revive – unavoidable	
1453	1330	2453	665	Petition to revive – unintentional	
1501	1330	2501	665	Utility issue fee (or reissue)	
1502	480	2502	240	Design issue fee	
1503	640	2503	320	Plant issue fee	
1460	130	1460	130	Patitions to the Commissioner	
1807	50	1807	50	Processing fee under 37 CFR 1.17(q)	
1806	180	1806	180	Submission of Information Disclosure Stmt	
8021	40	8021	40	Recording each patent assignment per property (times number of properties)	
1809	770	2809	385	Filing a submission after final rejection (37 CFR § 1.129(a))	
1810	770	2810	385	For each additional invention to be examined (37 CFR § 1.129(b))	
1801	770	2801	385	Raquest for Continued Examination (RCE)	
1802	900	1802	900	Request for expedited examination of a design application	

Other fee (specify) _____

*Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($)

SUBMITTED BY			
Name (Print/Type)	Karl R. Hermanns	Registration No. Attorney/Agent)	33,507
Signature		Date	April 29, 2004

Customer Number

00500

FUEL CELL SYSTEM WITH VARIABLE COANDA AMPLIFIERS FOR GAS RECIRCULATION AND SYSTEM PRESSURE REGULATION

BACKGROUND OF THE INVENTION

Field of the Invention

The present application relates to a Coanda flow amplifier, comprising a suction intake, an outlet, a fluid channel extending between the suction intake and the outlet, and a drive flow inlet, which is fluid-connected to the fluid channel via a drive-flow discharge slit, as well as to a method of operating a Coanda flow amplifier of this type. The application further relates to a fuel cell system comprising at least one fuel cell, one fluid source, one fluid line, and one Coanda flow amplifier arranged in the fluid line, whereby both a suction intake and an outlet of the Coanda flow amplifier are fluid-connected to the fluid line, and whereby a drive flow inlet of the Coanda flow amplifier is fluid-connected to the fluid source.

Description of the Prior Art

A Coanda flow amplifier of the above type is known in the art and has been described in US 5,974,802, for example. The operating principle of a Coanda flow amplifier is based on the phenomenon known as Coanda effect, *i.e.*, a fluid flowing along a curved surface tends to follow the outline of the curved surface. Consequently, a Coanda flow amplifier usually comprises an inlet for a fluid flow to be amplified, a fluid channel, which is bordered by a curved surface and which – along the flow direction of the flow to be amplified – at first narrows and subsequently widens with a funnel shape, as well as a fluid outlet. A drive-flow inlet is provided – radially with respect to the fluid channel – in an area upstream of the constriction of the fluid channel, whereby this inlet is fluid-connected with the fluid channel via a drive-flow discharge slit.

The drive-flow inlet serves to supply the Coanda flow amplifier with a drive fluid at a given intake pressure that subsequently reaches a high flow velocity – typically

sonic velocity – when passing through the drive-fluid discharge slit, and subsequently flows through the fluid channel along the surface that borders the fluid channel. This generates suction in the area of the intake of the Coanda flow amplifier, as a result of which large volumes of the fluid to be conveyed by the Coanda flow amplifier are sucked into the intake.

As described in US 5,974,802, a Coanda flow amplifier of this type can for example be arranged in the exhaust gas recirculation line of an internal combustion engine, to recirculate exhaust gases produced by the internal combustion engine.

DE 100 01 717 C1 describes the use of a Coanda flow amplifier in a fuel cell system, which comprises a fuel cell unit, a cathode gas supply line connected to the cathode side of the fuel cell unit, a cathode exhaust gas return line for the recirculation of cathode exhaust gas that is also connected to the cathode side of the fuel cell unit, as well as an anode exhaust gas return line that serves to recirculate the anode exhaust gas and is connected to the anode side of the fuel cell unit. The Coanda flow amplifier may for example be arranged in the cathode gas supply line and/or in the cathode exhaust gas return line of the fuel cell system, whereby a drive-flow inlet of the Coanda flow amplifier is connected to a compressed-air source via a compressed-air line. Alternatively, the Coanda flow amplifier may be arranged in the anode exhaust gas return line. In this case, the drive-flow inlet of the Coanda flow amplifier is connected to a fuel gas pressure tank, which may for example contain gaseous or liquid hydrogen.

As explained above, for the proper operation of the Coanda flow amplifier it is necessary that the drive fluid during its passage through the drive-flow discharge slit is accelerated to a very high flow velocity, typically the velocity of sound. This can be ensured if a pressure ratio between the discharge pressure of the drive flow when it leaves the drive-flow discharge slit and an intake pressure of the drive flow when it enters into the drive-flow discharge slit does not exceed a critical pressure ratio to be set in dependence on the desired flow velocity of the drive fluid when it leaves the drive-fluid discharge slit. For an acceleration of the drive-fluid flow to sonic velocity (Mach 1) and diatomic gases (Kappa = 1.4) the critical pressure ratio is calculated as 0.528. To prevent the critical

pressure ratio from being exceeded, *i.e.*, to ensure a proper functioning of the Coanda flow amplifier, the drive fluid is usually supplied to the Coanda flow amplifier at a sufficiently high supply pressure, which for example can be pre-set by means of a pressure controller.

But in some applications, in particular for the use of a Coanda flow amplifier in a fuel cell system, one faces the problem that the mass flow of the drive fluid to be supplied to the Coanda flow amplifier, and thus the drive fluid's supply pressure, will also be affected by other system parameters. For example, if the Coanda flow amplifier is to be used in a fuel cell system to recirculate the anode exhaust gas and if the fuel gas to be supplied to the anode side of the fuel cell is to be used as drive fluid, then the fuel gas volume to be supplied to the fuel cell depends on the fuel gas consumption in the fuel cell, *i.e.*, on the load state of the fuel cell. Thus, under low-load conditions of the fuel cell one may be faced with the problem that the pre-set intake pressure of the drive fluid is not sufficient to accelerate the drive-fluid flow to a sufficiently high velocity when it passes through the drive-fluid discharge slit, so that the proper functioning of the Coanda flow amplifier can no longer be ensured.

BRIEF SUMMARY OF THE INVENTION

The intention of the present systems and methods is to provide a Coanda flow amplifier, a method of operating a Coanda flow amplifier, as well as a fuel cell system equipped with a Coanda flow amplifier, whereby the proper functioning of the Coanda flow amplifier is to be ensured even if the mass flow rate of the drive fluid passing through the drive-fluid discharge slit of the Coanda flow amplifier is variable.

The above-mentioned task is solved by the present Coanda flow amplifiers, fuel cell systems and methods of operation . The Coanda flow amplifier according to the present systems and methods is characterized by the fact that a flow cross section of its drive-flow discharge slit can be variably adjusted. When one desires a low flow rate of the drive flow to be fed to the fluid channel of the Coanda flow amplifier, one can set an accordingly small flow cross section of the drive-flow discharge slit. Inversely, one can set a larger flow cross section of the drive-flow discharge slit if a greater flow rate of the drive

fluid is to be supplied to the fluid channel of the Coanda flow amplifier. Since the cross-sectional area of the drive-flow discharge slit for a critical flow is directly proportional to the flow rate of the drive fluid, it is possible to precisely meter the desired quantity of drive fluid to be supplied to the fluid channel of the Coanda flow amplifier by varying the cross-sectional area of the drive-flow discharge slit.

In addition, in the operation of the Coanda flow amplifier according to the present systems and methods, the cross-sectional area of the drive-flow discharge slit can be selected in dependence on the supply pressure of the drive fluid, so that when the drive-flow discharge slit is passed a pressure ratio between the output pressure of the drive-fluid flow when it leaves the drive-flow discharge slit and the intake pressure of the drive-fluid flow when it enters the drive-fluid discharge slit is established, which does not exceed the critical pressure ratio of the drive fluid. As a result, proper functioning of the Coanda flow amplifier can be ensured in a simple manner even in the case of varying mass flow rates of the drive fluid to be supplied to the fluid channel or in the case of varying supply pressures of the drive-fluid flow. Moreover, the need to employ a separate pressure controller to pre-set the supply pressure of the drive fluid is eliminated when using the Coanda flow amplifier according to the present systems and methods.

Preferably, the Coanda flow amplifier according to the present systems and methods is designed so that the drive-fluid discharge slit can be completely closed, *i.e.*, the supply of drive fluid into the fluid channel of the Coanda flow amplifier can be interrupted. As a result, a separate valve to interrupt the supply of drive fluid to the Coanda flow amplifier is no longer required.

In one embodiment, the Coanda flow amplifier comprises a flow-guiding element that is arranged between the suction intake and the outlet and is axially displaceable along the longitudinal axis of the Coanda flow amplifier. The fluid channel in the Coanda flow amplifier consists of a first section, which extends from the suction intake of the Coanda flow amplifier to an upstream face of the flow-guiding element, a second section executed in the flow-guiding element, and of a third section, which extends from

the downstream face of the flow-guiding element to the outlet of the Coanda flow amplifier.

In another embodiment, the suction intake of the Coanda flow amplifier is arranged in a first housing section, and the drive-flow discharge slit is formed between a downstream face of the first housing section and an upstream face of the flow-guiding element. As a result, the flow cross section of the drive-flow discharge slit is determined by the distance of the upstream face of the flow-guiding element from the downstream face of the first housing section and can be varied as desired in a simple manner by axially displacing the flow-guiding element along the longitudinal axis of the Coanda flow amplifier.

The second section of the fluid channel formed in the flow-guiding element may be bordered by a curved interior wall, so that the cross section of the second fluid channel section – starting from the upstream face of the flow-guiding element, in the flow direction of the fluid – in the fluid channel has a convergent divergent shape, *i.e.*, it initially narrows and then widens again. Because of the Coanda effect, drive fluid fed through the drive-flow discharge slit will flow with high velocity along the curved interior wall of the flow-guiding element, which gives rise to a suction effect in the area of the suction intake and thus to the flow-amplifying effect of the Coanda flow amplifier. The first fluid-channel section located in the first housing section has a constant cross section over its length. But alternatively, it is also possible to execute the first fluid-channel section in a downstream end area with a fluid-channel cross section that is divergent along the fluid flow direction, *i.e.*, with a cross section that widens along the fluid-flow direction in the fluid channel.

Preferably, at least in the area of the drive-flow discharge slit, the fluid-flow element is surrounded by a chamber that connects the drive-flow inlet with the drive-flow discharge slit. This chamber for example may be an annular chamber that at least partially surrounds the flow-guiding element and is fluid-connected to the drive-flow inlet that is arranged radially with respect to the flow-guiding element.

In yet another embodiment, the axially displaceable flow-guiding element of the Coanda flow amplifier carries through into a second housing section and is guided in the second housing section in a sealed manner.

As an axial guide for the flow-guiding element, the second housing section may for example contain a projection that projects radially inward, with an upstream face that forms the border of the chamber that at least partially surrounds the flow-guiding element. For the purpose of sealing the flow-guiding against the second housing section, a sealing element may be provided, which may for example be placed into a groove formed in the outer circumference of the flow-guiding element.

The outlet of the Coanda flow amplifier may be located in a third housing section, whereby a downstream section of the flow-guiding element protrudes into the third housing section and is guided in a sealing manner in the third housing section. In this case, the third section of the fluid channel is executed in the third housing section and may possess a constant cross section or a cross section that widens along the fluid flow direction in the fluid channel. The first, second, and third housing sections may be executed as separate components that may for example be connected to each other by means of a screw connection. Thus, the components of the Coanda flow amplifier can in a simple manner be installed in the housing that comprises three separate sections. In alternative embodiments the housing may be a single part, or the housing may comprise three housing sections in which any two of the three housing sections are executed as a single part.

When sealing the downstream section of the flow-guiding element with respect to the third housing section, one has to take into account that a gap will be present between the downstream face of the flow-guiding element and an upstream face on the third housing section when the drive-flow discharge slit is closed or only partially open, *i.e.*, when the flow-guiding element has been axially displaced against the fluid flow direction in the fluid channel. Thus, for the purpose of sealing this gap, a sealing element may be provided, which may be arranged in a groove executed on the third housing section and acts together with a circumferential surface of the flow-guiding element.

Moreover, because the movement that has to be executed by the flow-guiding element to set the flow cross section of the drive-flow discharge slit is very small, one can use quasi-static seals, such as for example cheap O-ring seals, to provide a seal between the flow-guiding element and the second and third housing section.

In another embodiment of the present systems and methods, the Coanda flow amplifier comprises an actuating element to axially displace the flow-guiding element. The actuating element may for example be arranged in the third housing section and in one embodiment, a piezo actuator is used for this purpose. If a piezo actuator is used, it becomes possible to very precisely control the movement to be executed by the flow-guiding element by means of a corresponding current to the piezo actuator, which makes it possible to very accurately adjust the flow cross section of the drive-flow discharge gap.

In an alternate embodiment of the present systems and methods, the flow-guiding element is resiliently pre-loaded opposite to the fluid flow direction in the fluid channel in order to close the drive-flow discharge slit when the actuating element is in its inoperative state (fail safe / NC). To generate the desired resilient pre-load, one may for example provide a spring element with ends that rest on the upstream face of the projection that is executed on the second housing section and protrudes radially inward and on a flange section that is executed on the outer circumference of the flow-guiding element and protrudes radially outward.

According to some embodiments of the present systems and methods of operating a Coanda flow amplifier, a variably adjustable flow cross section of the drive-flow discharge slit may be chosen in such a way that the pressure ratio of the output pressure of the drive flow when exiting from the drive-flow discharge slit and the intake pressure of the drive flow when entering the drive-flow discharge slit does not exceed a critical pressure ratio. The present systems and methods ensure that the drive-fluid flow during its passage through the drive-flow discharge slit is accelerated to a sufficiently high flow velocity – defined by the critical pressure ratio - even in the case of varying mass flow rates of the drive-fluid to be supplied to the fluid channel of the Coanda flow amplifier or

in the case of varying supply pressures of the drive-fluid flow, so that a proper functioning of the Coanda flow amplifier can be maintained.

For an ideal diatomic gas the critical pressure ratio has the value 0.528. If the flow cross section of the drive-flow discharge slit is chosen so that the pressure ratio between the output pressure of the drive flow when leaving the drive-flow discharge slit and the intake pressure of the drive flow when entering the drive-flow discharge slit does not exceed the critical pressure ratio, then it can be ensured that the drive-fluid flow during its passage through the drive-flow discharge slit is accelerated to at least sonic velocity (Mach 1).

The variable flow cross section of the drive-flow discharge slit may be adjusted so that the pressure ratio between the output pressure of the drive-flow when leaving the drive-flow discharge slit and the intake pressure of the drive-flow when entering the drive-flow discharge slit is equal to the critical pressure ratio. This implementation of the present systems and methods makes it possible to precisely control the flow velocity of the drive-fluid flow when it leaves the drive-flow discharge slit. This implementation may be at the point of the critical pressure ratio, since the momentum exchange between the drive-fluid flow and the fluid flow to be amplified is maximized for a drive-fluid flow that flows with sonic velocity when it leaves the drive-flow discharge slit, which may create a particularly good flow-amplifying effect of the Coanda flow amplifier.

In one embodiment of the present systems and methods, a Coanda flow amplifier is arranged in a fluid line, whereby the flow cross section of the drive-flow discharge slit can be variably adjusted. The use of a Coanda flow amplifier with a variably adjustable flow cross section of the drive-flow discharge slit makes it possible to ensure a proper functioning of the Coanda flow amplifier even in the case of varying supply pressures of the drive-fluid flow that is supplied from the fluid source to the drive-flow inlet of the Coanda flow amplifier. Furthermore, it becomes possible to reduce the number of components of the overall system, since for example a pressure controller, which for the purpose of pre-adjusting the supply pressure of the drive-fluid to be supplied to the Coanda

flow amplifier would be arranged at a fluid line connecting the fluid source with the drive-flow inlet, is no longer necessary.

In a first embodiment of the fuel cell system according to the present systems and methods, the role of the fluid line is played by a purge-gas feed line (feed) that is connected to the fuel cell and is used to introduce a purge gas, *e.g.*, air, into the fuel cell. The drive-flow inlet of the Coanda flow amplifier may for example be supplied with purge air via a pressurized-air line, *e.g.*, in the form of leakage air or overflow air from a high-pressure compressor or from another pressurized-air source in the system.

The Coanda flow amplifier then draws in a high flow volume of purge air from the surroundings into its suction intake. In addition to the fuel cell, other components of the fuel cell system may be connected with the purge-gas feed line and be ventilated by the purge-gas flow generated by the Coanda flow amplifier.

In a second embodiment of a fuel cell system, the role of the fluid line is played by a cathode gas feed line connected to the fuel cell that is used to supply the cathode side of the fuel cell with a cathode gas, for example air. In a manner similar to the one already described in connection with the first embodiment of the fuel cell system, the drive-flow inlet of the Coanda flow amplifier may for example be supplied via a pressurized-air line with air as drive fluid for the Coanda flow amplifier.

In a third embodiment of a fuel cell system, the role of the fluid line is played by a cold-starting-gas feed line that is connected to a cold-starting component of the fuel cell system and is used to supply a cold-starting gas to the cold-starting component during the cold-starting phase of the system. During a cold start, the role of the cold-starting component is to heat the fuel cell system to operating temperature as quickly as possible. Again, air can be used as drive fluid for the Coanda flow amplifier, whereby the air is supplied to the drive-flow inlet of the Coanda flow amplifier via a pressurized-air line.

In a fourth embodiment of a fuel cell system the role of the fluid line is played by an exhaust gas recirculation line for the recirculation of fuel cell exhaust gas. This exhaust gas recirculation line may for example be a cathode exhaust gas recirculation

line, which is used to return at least part of the cathode exhaust gas to the cathode inlet side of the fuel cell, for example in order to improve the water balance of the fuel cell system or to improve equipartition in the fuel cell. For the purpose of supplying a drive fluid to the Coanda flow amplifier, the drive-fluid inlet of the Coanda flow amplifier may for example be connected to a pressurized-air source via a pressurized-air line.

In alternative embodiments, the exhaust gas recirculation line is an anode exhaust gas recirculation line for the recirculation of anode exhaust gas, whereby the fuel cell is supplied with anode gas from the fluid source, *i.e.*, the anode gas that is to be supplied to the anode side of the fuel cell is at the same time used as drive fluid for the Coanda flow amplifier. The anode gas that is used as drive fluid for the Coanda flow amplifier may for example be gaseous hydrogen.

When using a Coanda flow amplifier in which the flow cross section of the drive-flow discharge slit can be variably adjusted, an appropriate choice of the flow cross section of the drive-flow discharge gap allows a very precise control of the mass flow rate of the anode gas to be supplied to the anode side of the fuel cell. Due to this, the Coanda flow amplifier additionally assumes a metering function to meter the anode gas volume, which is to be supplied to the anode side of the fuel cell and which is dependent on the load condition of the fuel cell.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a longitudinal section of one embodiment of a Coanda flow amplifier according to the present systems and methods.

Figure 2 shows a detail of the Coanda flow amplifier shown in Figure 1.

Figure 3 shows a diagrammatic representation of the design of a first embodiment of a fuel cell system according to the present systems and methods.

Figure 4 shows a diagrammatic representation of the design of a second embodiment of a fuel cell system according to the present systems and methods.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 shows a Coanda flow amplifier 10 with a three-part housing 12, comprising a first housing section 14, a second housing section 16, and a third housing section 18. Each of the first, second, and third housing sections is executed as a separate component and the three components are rigidly connected to each other by a screw connection 20. The Coanda flow amplifier 10 is equipped with a suction intake 22 in the first housing section 14 and an outlet 24 in the third housing section 18.

Arranged in the housing 12 is a flow-guiding element 26, which is guided in the housing 12 axially displaceable along a longitudinal axis L of the Coanda flow amplifier by a projection 28 of the second housing section 16 that protrudes radially inward, and which is sealed against the second housing section 16 by means of a first O-ring seal 30.

The first O-ring seal 30 is arranged in a groove 34 that is executed on an essentially cylindrical outer circumference 32 of the flow-guiding element 26. A downstream section 36 of the flow-guiding element 26 projects into the third housing section 18 and is guided in a sealed manner in the third housing section 18. For the purpose of sealing the downstream section 36 of the flow-guiding element 26 against the third housing section 18, a second O-ring seal 38 is provided that is arranged in a groove 40 executed on the third housing section 18.

A fluid channel 42 extends between the suction intake 22 and the outlet 24, whereby a first section 44 of the fluid channel 42 is executed in the first housing section 14, a second section 46 of the fluid channel 42 is executed in the flow-guiding element 26, and a third section 48 of the fluid channel 42 is executed in the third housing section 18. The first fluid-channel section 44 extends from the suction intake 22 to a downstream face 50 of the first housing section 14 and in a downstream end area possesses a cross section that widens along the fluid-flow direction F in the fluid channel 42. The second section 46 of the fluid channel 42, which is executed in the flow-guiding element 26, is bordered by a curved interior wall 52 of the flow-guiding element 26, so that – starting from the upstream face 54 of the fluid-guiding element 26 – the cross section of the second fluid-channel

section 46 at first narrows and subsequently widens again along the fluid-flow direction F in the fluid channel 42. The third section 48 of the fluid channel 42 executed in the third housing section 18 extends from an upstream face 58 on the third housing section 18 to the outlet 24 and possesses a constant cross section along the fluid-flow direction F in the fluid channel 42.

Radially with respect to the flow-guiding element 26, a drive-flow inlet (feed) 60 is arranged in the second housing section 16, whereby the drive-flow inlet 60 is fluid-connected with an annular chamber 64 – which surrounds an upstream section of the flow-guiding element 26 – via a connecting line 62.

As can be seen most clearly in Figure 2, the annular chamber 64 is connected with the fluid channel 42 in a fluid-conducting manner via a drive-flow discharge slit 66 that is formed between the downstream face 50 of the first housing section 14 and the upstream face 54 of the flow-guiding element 26. Thus, the flow cross section of the drive-flow discharge slit 66 is set by the distance of the downstream face 50 of the first housing section 14 from the upstream face 54 of the flow-guiding element 26 and can be variably adjusted by an axial displacement of the flow-guiding element 26 in the housing 12 along the longitudinal axis L of the Coanda flow amplifier 10. Pushing the flow-guiding element 26 sufficiently far against the fluid-flow direction F in the fluid channel 42, so that the upstream face 54 of the flow-guiding element 26 comes into contact with the downstream face 50 of the first housing section 14, interrupts the fluid connection between the drive-flow inlet 60 and the fluid channel 42, so that the supply of drive fluid into the fluid channel 42 of the Coanda flow amplifier 10 is interrupted.

An actuating element 68 that is executed as a piezo actuator is provided to effect the axial displacement of the flow-guiding element 26. A spring element, one end of which rests on an upstream face 72 of the projection 28 that projects radially inward and is formed on the second housing section 16, and the other end of which rests on a flange section 74 that projects radially outward and is formed on the outer circumference 32 of the flow-guiding element 26, resiliently pre-loads the flow-guiding element 26 in a direction opposite to the fluid-flow direction F in the fluid channel 42. As a result of the pre-loading

applied by the spring element 70, the upstream face 54 of the flow-guiding element 26 is pushed against the downstream face 50 of the first housing section 14, so that the drive-flow discharge slit 66 will be closed when the actuating element 68 is in its inactive state.

The mode of operation of the Coanda flow amplifier 10 shown in Figures 1 and 2 will be explained in the following. During its operation, the Coanda flow amplifier 10 is supplied via the suction intake 22 with a fluid flow to be amplified. The drive flow inlet 60 is connected with a drive-fluid source, from which the Coanda flow amplifier 10 is supplied with pressurized drive fluid. Should the flow-amplifying effect of the Coanda flow amplifier 10 not be desired during certain operating phases, then the piezo actuator is not supplied with energy, so that the drive-flow discharge gap 66 remains closed due to the pre-load applied onto the flow-guiding element 26 by the spring element 70, as a result of which the supply of drive fluid into the fluid channel 42 of the Coanda flow amplifier 10 is interrupted.

On the other hand, if the flow-amplifying effect of the Coanda flow amplifier 10 is desired, then the flow-guiding element 26 is shifted by the piezo actuator along the fluid flow direction F in the fluid channel 42, which opens the fluid connection between the drive-fluid inlet 60 and the fluid channel 42. During this, the flow cross section of the drive-flow discharge slit 66 is chosen by a suitable displacement of the flow-guiding element 26 in such a way that the desired mass flow rate of drive fluid is supplied to the fluid channel 42.

An optimum momentum exchange between the drive fluid flowing through the drive-flow discharge slit 66 and the fluid flow supplied via the suction intake 22 is possible if the drive fluid flows with sonic velocity (Mach 1) when leaving the drive-flow discharge slit 66. This can be implemented, if a pressure ratio between an output pressure of the drive-fluid flow when it leaves the drive-flow discharge slit 66 and an intake pressure of the drive-fluid flow when it enters into the drive-flow discharge slit 66 is less or equal to a critical pressure ratio. Consequently, the flow cross section of the drive-flow discharge slit 66 is adjusted in such a way that the pressure ratio between an output pressure of the drive-fluid flow when it leaves the drive-flow discharge slit 66 and an

intake pressure of the drive-fluid flow when it enters into the drive-flow discharge slit 66 equals the critical pressure ratio. The adjustment of the desired flow cross section of the drive-flow discharge gap 66 is accomplished by supplying the piezo actuator with a suitable current with the help of control signals, which are provided by an electronic control unit that is not shown in the figures.

The drive-fluid that exits the drive-flow discharge slit 66 with sonic velocity flows along the curved interior wall 52 of the flow-guiding element 26 because of the Coanda effect. This creates a suction effect in the area of the suction intake 22, as a result of which large volumes of the fluid to be conveyed by the Coanda flow amplifier 10 are sucked into the suction intake 22.

Figure 3 shows the configuration of a first embodiment of a fuel cell system 80, which comprises a fuel cell 82, a purge-gas feed line 84 that is connected to the fuel cell 82, as well as a purge-gas discharge line 86. A Coanda flow amplifier 10 (shown in Figures 1 and 2) is arranged in the purge-gas feed line 84, whereby both the suction intake (suction) 22 and the outlet (discharge) 24 of the Coanda flow amplifier 10 are connected to the purge-gas feed line 84. The drive-flow inlet 60 of the Coanda flow amplifier 10 is connected to a pressurized-air source 88 via a pressurized-air line 87.

During operation, the drive-flow inlet 60 of the Coanda flow amplifier 10 is supplied by the pressurized-air source 88 with pressurized air as drive fluid via the pressurized-air line 87. As a result of the suction effect being generated at the suction intake 22 of the Coanda flow amplifier 10, a high flow volume of purge air is drawn in from the surroundings and is supplied to the fuel cell 82 via the purge-gas feed line 84.

During this, the flow cross section of the drive-flow discharge gap of the Coanda flow amplifier 10 is chosen so that the pressure ratio between the output pressure of the drive-fluid flow when it leaves the drive-flow discharge slit 66 and the intake pressure of the drive-fluid flow when it enters into the drive-flow discharge slit 66 equals the pressure ratio of 0.528. The adjustment of the flow cross section of the drive-flow discharge slit is accomplished by supplying the piezo actuator of the Coanda flow amplifier

10 with a suitable current with the help of control signals, which are provided by an electronic control unit that is not shown in Figure 3.

Figure 4 shows a further embodiment of a fuel cell system 90, which comprises a fuel cell 92 with a cathode side 94, an anode side 96, and a membrane 98 separating the cathode side 94 and the anode side 96. A first Coanda flow amplifier 10 (shown in Figures 1 and 2) is arranged in a cathode gas feed line 100, whereby both the suction intake 22a and the outlet 24a of the Coanda flow amplifier 10a are connected to the cathode gas feed line 100. The drive-flow inlet 60a of the Coanda flow amplifier 10a is connected to a pressurized-air source 102 via a pressurized-air line 101.

During operation, the drive-flow inlet 60a of the Coanda flow amplifier 10a is supplied by the pressurized-air source 102 with pressurized air as drive fluid via the pressurized-air line 101. As a result, air is drawn from the surroundings into the suction intake 22a of the Coanda flow amplifier 10a and is supplied to the cathode side 94 of the fuel cell 92 via the cathode gas feed line 100.

Cathode exhaust gas that has been discharged on the cathode side 94 of the fuel cell 92 via a discharge line 104, is at least partially recirculated to the cathode side 94 of the fuel cell 92 via a cathode exhaust gas return line 106, whereby for the purpose of regulating the volume of cathode exhaust gas to be recirculated, the discharge line 104 is connected with the cathode exhaust gas recirculation line 106 by a switchable valve that is not shown in Figure 4. A second Coanda flow amplifier 10b (shown in Figures 1 and 2) is arranged in the cathode exhaust gas recirculation line 106, whereby both the suction intake 22b and the outlet 24b of the Coanda flow amplifier 10b are connected with the cathode exhaust gas recirculation line 106. The drive-flow inlet 60b of the Coanda flow amplifier 10b is connected to a further pressurized-air source 110 via a further pressurized-air line 108.

During operation, the drive-flow inlet 60b of the Coanda flow amplifier 10b is supplied by the further pressurized-air source 110 with pressurized air as drive fluid via the pressurized-air line 108. In this manner, the Coanda flow amplifier 10b provides a gas-

flow drive for the cathode exhaust gas that is to be returned to the cathode side 94 of the fuel cell 92 via the cathode exhaust gas recirculation line 106.

Anode exhaust gas leaving the anode side 96 of the fuel cell 92 is returned to the anode side 96 of the fuel cell 92 via an anode exhaust gas return line 112. A third Coanda flow amplifier 10c (shown in Figures 1 and 2) is arranged in the anode exhaust gas return line 112, whereby both the suction intake 22c and the outlet 24c of the Coanda flow amplifier 10c are connected to the anode exhaust gas return line 112. The drive-flow inlet 60c of the Coanda flow amplifier 10c is connected via a line 114 to an anode gas tank 116, which contains gaseous or liquid hydrogen.

During operation, the drive-flow inlet 60c of the Coanda flow amplifier 10c is supplied by the anode gas tank 116 with anode gas as drive fluid via the line 114. In this, the flow cross section of the drive-flow discharge slit of the Coanda flow amplifier 10c is chosen so that the desired anode gas volume – which is dependent on the load state of the fuel cell 92 – is supplied to the anode side 96 of the fuel cell 92. As already described in connection with the Coanda flow amplifier 10b arranged in the cathode exhaust gas return line 106, the Coanda flow amplifier 10c provides a gas-flow drive for the anode exhaust gas to be returned to the anode side 96 of the fuel cell 92 via the anode exhaust gas recirculation line 112.

During operation of the fuel cell system 90, each of the flow cross sections of the drive-flow discharge slits of the Coanda flow amplifiers 10a, 10b, 10c is chosen so that the pressure ratio between the output pressure of the drive-fluid flow when it leaves the drive-flow discharge slit of the respective Coanda flow amplifier 10a, 10b, 10c and the intake pressure of the drive-fluid flow when it enters into the drive-flow discharge slit of the respective Coanda flow amplifier 10a, 10b, 10c is equal to the critical pressure ratio of 0.528. The adjustment of the flow cross sections of the drive-flow discharge slits is accomplished by supplying the respective piezo actuator of the Coanda flow amplifiers 10a, 10b, 10c with suitable currents with the help of control signals, which are provided by an electronic control unit that is not shown in Figure 4.

CLAIMS

1. Coanda flow amplifier (10, 10a, 10b, 10c), comprising

one suction intake (22, 22a, 22b, 22c),

one outlet (24, 24a, 24b, 24c)

one fluid channel (42) extending between the suction intake (22, 22a, 22b, 22c) and the outlet (24, 24a, 24b, 24c),

one drive-flow inlet (60, 60a, 60b, 60c) that is in fluid-connection with the fluid channel (42) via a drive-flow discharge slit (66),

characterized in that the flow cross section of the drive-flow discharge slit (66) is variably adjustable.

2. Coanda flow amplifier according to claim 1, characterized in that the drive-flow discharge slit (66) can be completely closed.

3. Coanda flow amplifier according to claim 1 or 2, characterized in that the Coanda flow amplifier (10, 10a, 10b, 10c) comprises a flow-guiding element (26) that is arranged between the suction intake (22, 22a, 22b, 22c) and the outlet (24, 24a, 24b, 24c) and is axially displaceable along a longitudinal axis (L) of the Coanda flow amplifier (10, 10a, 10b, 10c).

4. Coanda flow amplifier according to claim 3, characterized in that the suction intake (22, 22a, 22b, 22c) is arranged in a first housing section (14) and the drive-flow discharge slit (66) is formed between a downstream face (50) of the first housing section (14) and an upstream face (54) of the flow-guiding element (26).

5. Coanda flow amplifier according to claim 3 or 4, characterized in that at least in the area of the drive-flow discharge slit (66), the flow-guiding element (26) is surrounded by a chamber (64) that connects the drive-flow inlet (60, 60a, 60b, 60c) with the drive-flow discharge slit (66).

6. Coanda flow amplifier according to claim 5, characterized in that the axially displaceable flow-guiding element (26) carries through to the second housing section (16) and is guided in the second housing section (16) in a sealed manner.

7. Coanda flow amplifier according to one of claims 3 to 6, characterized in that the outlet (24, 24a, 24b, 24c) is arranged in a third housing section (18), whereby a downstream section (36) of the flow-guiding element (26) protrudes into the third housing section (18) and is guided in the third housing section (18) in a sealed manner.

8. Coanda flow amplifier according to claim 7 characterized in that a sealing element (38) – to seal the flow-guiding element (26) against the third housing section (18) – is arranged in a groove (40) formed on the third housing section (18) and works together with a circumferential surface (32) of the flow-guiding element (26).

9. Coanda flow amplifier according to one of claims 6 to 8, characterized in that quasi-static sealing elements are provided to seal the flow-guiding element (26) against the second and/or third housing section (16, 18).

10. Coanda flow amplifier according to one of claims 3 to 9, characterized in that an actuating element (68) is provided to effect the axial displacement of the flow-guiding element (26).

11. Coanda flow amplifier according to claim 10, characterized in that the actuating element (68) is a piezo actuator.

12. Coanda flow amplifier according to one of claims 10 or 11, characterized in that the flow-guiding element (26) is resiliently pre-loaded in a direction opposite to the fluid-flow direction (F) in the fluid channel (42) to close the drive-flow discharge slit (66) when the actuating element (68) is in its inactive state.

13. Method to operate a Coanda flow amplifier (10, 10a, 10b, 10c) of one of claims 1 to 11, comprising the following steps:

feeding a fluid flow that is to be amplified to a suction intake (22, 22a, 22b, 22c),

feeding a drive-flow to a drive-flow inlet (60, 60a, 60b, 60c), whereby the drive-flow inlet (60, 60a, 60b, 60c) is fluid-connected by a drive-flow discharge slit (66) to a fluid channel (42) that extends between the suction intake (22, 22a, 22b, 22c) and an outlet (24, 24a, 24b, 24c),

characterized in that a variable flow cross section of the drive-flow discharge slit (66) is adjusted in such a way so that a pressure ratio between the output pressure of the drive flow when it leaves the drive-flow discharge slit (66) and an intake pressure of the drive flow when it enters the drive-flow discharge slit (66) does not exceed a critical pressure ratio.

14. Method according to claim 13, characterized in that the variable flow cross section of the drive-flow discharge slit (66) is adjusted so that the pressure ratio between the output pressure of the drive flow when it leaves the drive-flow discharge slit (66) and the intake pressure of the drive flow when it enters the drive-flow discharge slit (66) is equal to the critical pressure ratio.

15. Fuel cell system (80; 90) comprising

at least one fuel cell (82; 92),

one fluid source (88; 102, 110, 116),

one fluid line (84; 100, 106, 112),

one Coanda flow amplifier (10; 10a, 10b, 10c) arranged in the fluid line (84; 100, 106, 112), whereby both a suction intake (22; 22a, 22b, 22c) and an outlet (24; 24a, 24b, 24c) of the Coanda flow amplifier (10; 10a, 10b, 10c) are fluid-connected to the fluid line (84; 100, 106, 112), and whereby a drive-flow inlet (60; 60a, 60b, 60c) of the Coanda flow amplifier (10; 10a, 10b, 10c) is fluid-connected to the fluid source (88; 102, 110, 116),

characterized in that the Coanda flow amplifier (10; 10a, 10b, 10c) is a Coanda flow amplifier (10; 10a, 10b, 10c) according to one of claims 1 to 11.

16. Fuel cell system according to claim 15, haracterized in that the fluid line (84; 100, 106, 112) is a purge-gas feed line (84) that is connected to the fuel cell (82).

17. Fuel cell system according to claim 15, characterized in that the fluid line (84; 100, 106, 112) is a cathode gas supply line (100) that is connected to the fuel cell (82).

18. Fuel cell system according to claim 15, characterized in that the fluid line (84; 100, 106, 112) is a cold-starting-gas supply line that is connected to a cold-starting component.

19. Fuel cell system according to claim 15, characterized in that the fluid line (84; 100, 106, 112) is an exhaust-gas recirculation line (106, 112) for the recirculation of fuel cell exhaust gas.

20. Fuel cell system according to claim 19, characterized in that the exhaust gas recirculation line (106, 112) is an anode-exhaust-gas recirculation line (112) for the recirculation of anode exhaust gas and that anode gas is supplied to the fuel cell (92) from the fluid source (116).

ABSTRACT

A Coanda flow amplifier comprises one suction intake, one outlet, one fluid channel extending between the suction intake and the outlet, and one drive-flow inlet, which is fluid-connected to the fluid channel via a drive-flow discharge slit, whereby the flow cross section of the drive-flow discharge slit is variably adjustable. In a method to operate the Coanda flow amplifier, the variably adjustable flow cross section of the drive-flow discharge slit is chosen so that a pressure ratio between an output pressure of the drive flow when it leaves the drive-flow discharge slit and an intake pressure of the drive flow when it enters the drive-flow discharge slit does not exceed a critical pressure ratio. A fuel cell system comprises at least one fuel cell, one fluid source, one fluid line, and one Coanda flow amplifier arranged in the fluid line, whereby the Coanda flow amplifier is equipped with a drive-flow discharge slit with a variably adjustable flow cross section.

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Docket No. 130309.496P1
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Express Mail No. EV335606213US

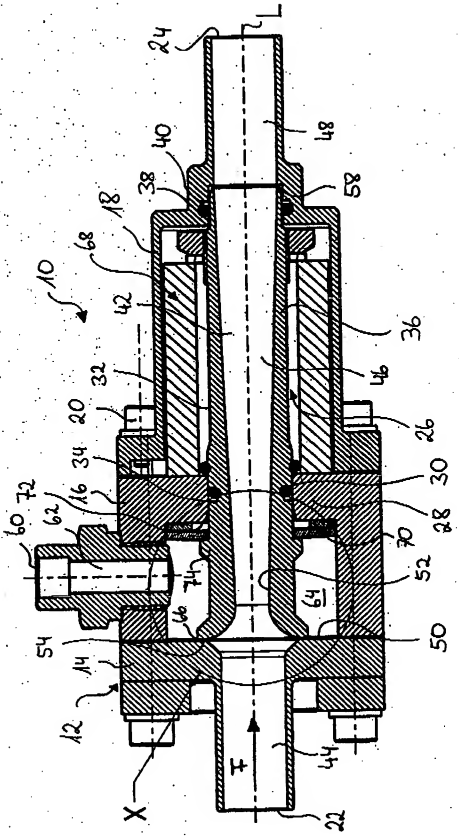


FIGURE 1

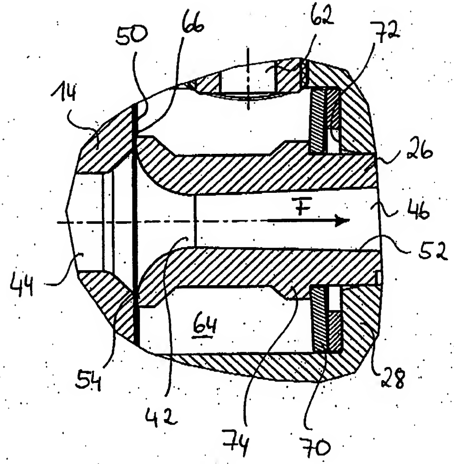
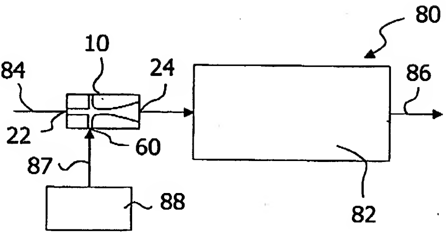


FIGURE 2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10
84
24
86
22
60
87
88
82

Fig. 3

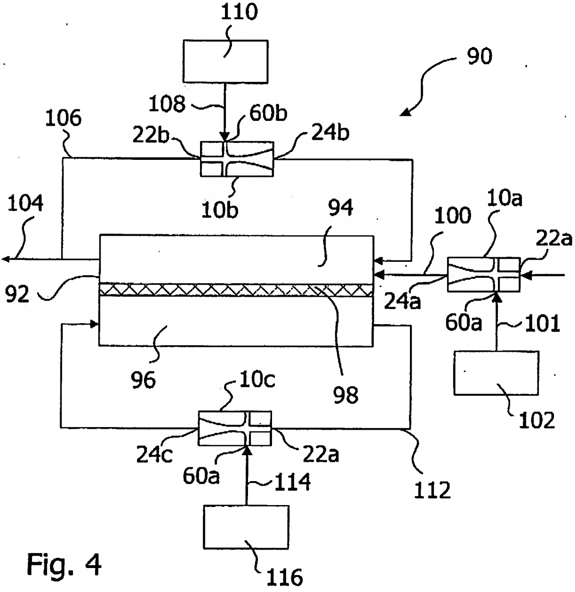
110
90
108
60b
106
22b
24b
104
10b
94
100
10a
22a
92
24a
60a
101
96
10c
98
102
24c
22a
60a
114
112
116

Fig. 4

APPLICATION DATA SHEET

Application Information

Application number::	
Filing Date::	
Application Type::	Provisional
Subject Matter::	Utility
Suggested classification::	
Suggested Group Art Unit::	
CD-ROM or CD-R?::	None
Number of CD disks::	
Number of copies of CDs::	
Sequence submission?::	
Computer Readable Form (CRF)?::	No
Number of copies of CRF::	
Title ::	FUEL CELL SYSTEM WITH VARIABLE COANDA AMPLIFIERS FOR GAS RECIRCULATION AND SYSTEM PRESSURE REGULATION
Attorney Docket Number::	130309.496P1
Request for Early Publication?::	No
Request for Non-Publication?::	No
Suggested Drawing Figure::	
Total Drawing Sheets::	3
Small Entity?::	No
Petition included?::	No
Petition Type::	
Licensed U.S. Gov't Agency::	
Contract or Grant No::	
Secrecy Order in Parent Appl.?::	No

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State or Province of mailing address::	
Country of mailing address::	Germany
Postal or Zip Code of mailing address::	73728

Correspondence Information

Correspondence Customer Number :: **00500**

Representative Information

Representative Customer Number::		**00500**

Domestic Priority Information

Application ::	Continuity Type::	Parent Application::	Parent Filing Date::

Foreign Priority Information

Country::	Application number::	Filing Date::	Priority Claimed::

Assignee Information

Assignee name::	
Street of mailing address::	
City of mailing address::	
State or Province of mailing address::	
Country of mailing address::	
Postal or Zip Code of mailing address::	